2062
Office Copy

INVESTIGATION OF PCB CONTAMINATION IN THE PETERBOROUGH AREA

AUGUST 1992

Ontario

Environment
Environnement

18-08-92

ISBN 0-7778-0085-3

INVESTIGATION OF PCB CONTAMINATION IN THE PETERBOROUGH AREA

Report prepared by:

S.H. Maude
Central Region

K. Sherman, A. Hayton, and K. Suns
Water Resources Branch

AUGUST 1992

Cette publication technique
n'est disponible qu'en anglais.

PIBS 2062

SUMMARY

Detailed investigations of polychlorinated biphenyl (PCB) contamination in the Peterborough area have been undertaken since 1983. The objectives were:

1. to identify sources of PCB contamination to the Otonabee River and Rice Lake;

2. to define the spatial extent of PCB contamination in the study area;

3. to determine temporal trends in the bioaccumulation of PCBs;

4. to recommend remedial options.

Stormwater runoff from the Rink Street and the Park Street storm sewer systems in the City of Peterborough has been identified as the primary source of bioavailable PCBs to the aquatic system. Erosion of PCB-contaminated sediments is thought to be the primary mechanism of downstream PCB transport in the Otonabee River.

Enhanced PCB availability extends downstream from Little Lake in Peterborough to Rice Lake and throughout Rice Lake from the mouth of the Otonabee River primarily in a north-easterly direction as far as Seymour Lake, located 80 km downstream of Peterborough.

Analyses of sectioned sediment cores suggest that PCB inputs are lower now than they have been in the past. PCB levels in young-of-the-year yellow perch collected from Rice Lake have fluctuated considerably over the 12 years of record; tissue PCB levels reached a maximum in 1985 and have since returned to lower levels. Mussel biomonitoring data suggest that the quantity of PCBs being discharged from the Park Street storm sewer declined between 1985 and 1989; there has been no evidence of a similar decline for the Rink Street storm sewer.

PCB levels in young-of-the-year yellow perch exceeded the IJC Aquatic Life Guideline of 100 ng/g at all sampling sites on the Otonabee River and Rice Lake, except for the control sites located upstream of Peterborough. Consumption restrictions are advised for large carp from Rice Lake and the lower Otonabee River due to tissue PCB concentrations over the Federal guideline of 2000 ng/g. Other species of sport fish tested have PCB levels below the Federal guideline.

It is recommended that abatement action directed at reducing PCB discharges from the Rink Street and the Park Street storm sewer systems be continued. In conjunction with this, a biomonitoring program is recommended to assess the effectiveness of the abatement measures.

ACKNOWLEDGEMENTS

J. Beaver, B. Hancock, P. Hughes, R. Jaagumagi, and R. Shaw provided helpful review comments. Their contributions are gratefully acknowledged.

LIST OF FIGURES AND TABLES

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Purpose of the Study

In 1976, Ministry of the Environment (MOE) staff became aware of the potential for contamination by polychlorinated biphenyls (PCBs) in the Peterborough area. Tissue analysis of fish collected downstream of the City of Peterborough in that year indicated elevated levels of PCBs. PCB levels in these fish were well below the 2000 ng/g Federal guideline for human consumption and were, therefore, not considered to be of immediate serious concern. Monitoring of fish, however, was continued in the area to establish long-term trends.

In 1983, a complaint was received from the licenced commercial fisherman who had fished carp (*Cyprinus carpio* Linnaeus) in Rice Lake for over 25 years. He had discontinued fishing carp in 1982 due to PCB contamination of his catch. The Federal Department of Fisheries and Oceans had tested samples of the fisherman's carp since 1977. In 1982, the Department had restricted the sale of the catch by requiring testing of each shipment prior to sale. In response to the complaint from the fisherman, preliminary investigations were undertaken during 1983 and 1984 with a more comprehensive survey taking place from 1985 to 1990. The following objectives applied to the survey:

- identify active sources of PCB contamination to the Otonabee River and Rice Lake;
- define the spatial extent of PCB contamination in the Otonabee River and Rice Lake;
- continue historical trend analysis;
- consider options for source remediation as applicable.

1.2 Characteristics and Environmental Fate of PCBs

PCBs are a class of very stable man-made organic compounds. The value of PCBs in industry was due chiefly to their excellent electrical insulating properties under a

wide range of temperatures. This same property of stability that gave PCBs industrial value also accounts for their persistence in the environment.

PCBs were used in the past as:

- insulating fluids in industrial capacitors and transformers;
- an additive in hydraulic oils and lubricants;
- plasticizing agents;
- flame retardents.

PCBs are no longer manufactured or used in the manufacture of new products. However, in-service storage of PCBs continues wherever older capacitors and transformers remain in use. In addition, waste PCBs in liquid and on solids represent a significant amount of storage. An estimated 9569.5 tonnes of PCBs can be accounted for in Ontario. Of this amount, most is located in electrical transformers still in use, with lesser amounts in electrical capacitors and in storage awaiting disposal (Strachan 1988). The present monitoring and use requirements for PCBs minimize the chance of release to the environment. Those discharges of PCBs that occurred prior to strict controls are still of concern because the residual transport of PCBs from the discharge areas may represent active sources of contamination, whether they are areas of terrestrial soils or aquatic sediments.

In North America, the sole manufacturer of PCBs was the Monsanto Company in the United States. PCBs were marketed as mixtures of molecules of differing chlorine content with the trade name "Aroclor". Aroclors were given a four digit identification number, the last two digits of which generally represented the average percent chlorine content. For example, Aroclor 1242 was a PCB mixture containing 42% chlorine by weight.

PCBs are generally highly resistant to chemical reaction and thus to degradation in the environment. Because PCBs are mixtures of many different PCB molecules (Shiu and Mackay 1986), each with different degradation, transport and accumulation rates (Neely 1983), PCB mixtures as analysed in environmental samples will appear to "weather". The more reactive PCB molecules will degrade or be transported to or from a water body earlier than those less reactive molecules. The degree of reactivity of PCBs tends to vary with the degree of chlorination (Shiu and McKay 1986). Lower chlorinated PCBs are generally less persistent in the environment than higher chlorinated PCBs (Moore and Ramamoorthy 1984). For example, Aroclor 1260 will tend to persist much longer in the environment than Aroclor 1242 because

of the greater degree of chlorination of the predominant PCB molecules in these mixtures.

In general, PCBs are sparingly soluble in water and highly soluble in organic solvents or fats. This means that when discharged to water, rather than dissolving, they are sorbed onto particles and readily taken up and accumulated in the fatty tissues of aquatic organisms. This process, by which chemicals are accumulated by organisms directly or through food consumption, is called bioaccumulation. The ratio of partitioning of PCBs between organism and water (the bioconcentration factor) ranges between 10^3 and 10^6 (Strachan 1988). In other words, even at a relatively low concentration of PCB in water, relatively high concentrations in fish and other aquatic organisms may occur.

The toxicity of PCBs has been reviewed by Roberts et al. (1978), MOE (1979), and Eisler (1986). Even at water concentrations below 100 ng/L, PCBs can have sublethal effects on aquatic organisms and fish-eating birds and mammals, including reproductive failure and liver dysfunction. The high degree of bioaccumulation of PCBs in fish and other organisms from water dictates that very low water concentrations must be maintained to prevent high levels in the food chain.

1.3 Study Area

Figure 1.1 shows the overall study area from Katchewanooka Lake downstream to Trenton on the Trent River. The Otonabee River passes through the City of Peterborough and discharges to Rice Lake some 30 km downstream of the City. The area is part of the Trent-Severn Waterway and, as such, receives heavy recreational use during the summer.

1.3.1 Historical Uses of PCBs

Five PCB Aroclors have been used in the Peterborough area. Aroclors 1016, 1242 and 1254 were extensively used at Canadian General Electric (CGE) from 1947 to 1978 in the manufacture of capacitors. Some servicing of transformers (in which Aroclors 1258 and 1260 were used) also occurred at CGE. Extensive in-service storage of Aroclors 1258 and 1260 in transformers and turbines has also occurred in companies and utilities in Peterborough from 1930 to the present. Extensive use of hydraulic fluids containing PCBs was made at Outboard Marine Corporation (OMC) until the mid 1970s when these fluids began to be replaced with oil containing no

PCBs. Present in-service storage of PCBs in the Peterborough area electrical equipment is 110,000 L (approximately 165 tonnes) (MOE 1984a).

1.3.2 Water Uses

Little Lake is located within the City of Peterborough and is used for boating, waterskiing, canoeing, sailing, windsurfing, swimming and fishing. There is a relatively large marina which provides temporary mooring on the western shore of Little Lake at Crary Park. Several parks with water frontage and two public beaches are located on the lake. The lake forms an aesthetic focal point for the City with extensive public access to view special events such as regattas and sailing competitions and a large decorative fountain.

Little Lake and the Otonabee River receive drainage from the City of Peterborough storm sewer system through a series of outfalls. In total, there are approximately 200 storm sewer outfalls within the City (Theil and Beak 1989). The immediate area draining to Little Lake consists of urban and agricultural land with minor forested portions. There is a mixture of land uses within the City. Two large industries, Canadian General Electric (CGE) and Outboard Marine Corporation (OMC) are located, in part, within the immediate drainage of Little Lake. Treated sewage effluent is discharged to the Otonabee River downstream of Little Lake from the City of Peterborough Water Pollution Control Plant.

The shorelines of the Otonabee River and Rice Lake have heavy cottage development. Rice Lake has a very productive warm-water fishery for a variety of species including: walleye (*Stizostedion vitreum* (Mitchill)), yellow perch (*Perca flavescens* (Mitchill)), sunfish (*Lepomis* spp.), muskellunge (*Esox masquinongy* Mitchill), largemouth bass (*Micropterus salmoides* (Lacepede)) and smallmouth bass (*M. dolomieui* Lacepede). Commercial fishing has historically been carried out for carp and brown bullheads (*Ictalurus nebulosus* (Lesueur)) with an incidental catch of perch and sunfish.

1.3.3 Hydrology, Morphometry and Sedimentation

The Otonabee River drains a large area upstream of Peterborough (7,360 km^2). The river is a highly regulated system with nine dams between Lakefield and the outlet of Rice Lake. Summer water levels are controlled for navigational and recreational

use. Fall and winter levels are lowered for flood control purposes. Mean annual discharge of the Otonabee River is 83.4 m^3/s (Taylor 1985).

Little Lake is a small (surface area = 0.73 km^2), relatively shallow (mean depth = 2.8 m) lake with the deepest area (9.75 m) located in a southern embayment somewhat sheltered from the main current of the river. The lake volume is small relative to the discharge volumes of the Otonabee River resulting in a rapid flushing rate.

Rice Lake is a large (surface area = 100 km^2), shallow (mean depth = 2.4 m) nutrient-enriched lake. The main inflow to the lake is the Otonabee River. Other inflows include the Indian River, Ouse River and minor tributary drainage, all of which drain mixed agricultural and swamp land.

To understand the distribution and transport of PCBs in the study area it is important to understand the movement and accumulation of sediment. PCBs have a high affinity to bind or sorb to sediment particles in water and soil (Karickhoff *et al.* 1979). They tend to bind more readily to fine organic sediment such as mud or ooze than to coarse inorganic sands and gravels, however, because PCBs may enter aquatic systems in an oil matrix already bound to a substrate, they may well be found on coarse sediment at sites directly influenced by an active source of PCBs. In this study, total organic carbon (TOC) was used as an indicator of the organic content of the sediment samples collected.

Erosion and deposition strongly influence the distribution of PCB-contaminated sediments in a natural river system. However, the influence of these forces on the spatial distribution of PCB-contaminated sediments may be overriden by the presence of an active source of PCBs which can locally influence the sediment PCB concentrations. Areas of high sediment PCB concentration can act as continuing sources of contamination even after abatement of land-based sources. PCBs on resuspended sediments can be carried by currents and taken up by downstream biota.

Fast currents in the Otonabee River have an overriding influence on sediment accumulation. Apart from some minor quiescent shoreline areas along the river, the deep basin of Little Lake is likely the only area where long-term sediment accumulation occurs en route to Rice Lake. Rice Lake is the first significant area downstream of the City of Peterborough where permanent sediment accumulation can occur.

At the inlet to Little Lake, the main inflow from the Otonabee River is deflected at Crary Park Marina and travels east across the lake, turning southward at Cemetery Point toward the outlet at Trent-Severn Waterway Lock 19. Current and circulation patterns within Little Lake are variable depending on the Otonabee River flow rates. The deep southern embayment area appears to undergo some flushing even during low flow conditions, however, current velocities are low and circulation here is minimal. Greater water exchange between this deep basin and the main inflow occurs under high flow conditions. In the deep basin, a clockwise circulation pattern typically occurs, particularly in the western end (MacLaren Plansearch 1989).

The bed of Rice Lake is generally soft ooze with more granular material or peat near shore in depths less than 2 m. Currents are largely generated by winds with the Otonabee River flow having a localized influence in the area of the river mouth. Under conditions of high river flows, sediment carried by the Otonabee River disperses into Rice Lake in a predominantly easterly direction from the river mouth. However, during the remainder of the open-water season, resuspension of surficial sediments could occur over large areas of the shallow western half of the lake with dispersion in both easterly and westerly directions. Considerable resuspension of sediment is also possible in the vicinity of river mouths due to the foraging and mating activities of carp (Scott and Crossman 1973). The lake is ice covered through the winter period (January to March) with little resuspension occurring with the possible exception of river mouths.

The Rice Lake basin is essentially divided into two by the remnants of a former railroad causeway running south to north across the lake between Harwood and Hiawatha. The railway bed breaks or approaches the water surface for all but 19% of its 4 km length, while 60% of the cross-sectional area along the crossing occurs at this relatively narrow central gap. This feature, then, could represent a considerable barrier to the fluvial transport of sediment. The eastern end of Rice Lake, which gradually narrows to the lake's outlet to the Trent River at the dam in Hastings represents another area for the settling of suspended material within the lake.

2.0 METHODS

2.1 Monitoring of Potential Sources

2.1.1 Sewage Treatment Plant (STP)

The Peterborough STP is a conventional activated sludge plant with a design flow of 68,190 m^3/day (MOE 1988). Treated effluent discharges to the Otonabee River just upstream of Highway 7.

Twenty-four-hour composite samples of influent raw sewage and final effluent were collected for PCB analysis on 53 occasions from 1985 to 1988. To achieve a lower analytical detection limit, higher volume composite samples of final effluent were collected in September, 1987 and July, 1988. From 1985 to 1987, 68 grab samples of sewage sludge were collected and analysed for PCB content.

2.1.2 Catch-Basin Sediment

In 1985, a synoptic survey of sediment accumulated in storm sewer catch basins was undertaken. Grab samples of sediment for PCB analysis were collected from 25 locations to determine the areal extent of PCB-contaminated sediment in the City's storm sewer system.

2.1.3 Stormwater Sampling

Sampling of the stormwater runoff from various storm sewer drainage areas within the City was undertaken from 1984 to 1988. Single grab samples were collected on eleven occasions in 1985 and two occasions in 1986 from ten locations during storms. The purpose of this sampling was to determine the range of PCB concentrations in stormwater at various locations within the City.

Other storm sewer locations were sampled in a more intensive fashion. Initially, a number of storm sewer locations were sampled. Based on a review of the data obtained and an increased understanding of the physical layout of the storm sewer system, the number of storm sewers monitored was reduced to those two considered to be the most significant contributors of PCB-contaminated stormwater. These two, the Rink Street and the Park Street storm sewer systems, then became the primary

foci of the stormwater monitoring program. The areas drained by these systems and the locations of sampling are shown in Figure 2.1.

At each of these two locations, stormwater samples were collected at frequent intervals throughout the duration of storm events. Initially, samples were analysed only for PCBs, however, in 1988, all samples were also analysed for conductivity and total suspended solids.

Both the Rink Street and Park Street storm sewer systems have continuous base flows due to industrial cooling water discharges. In 1987 and 1988, samples were collected during dry weather conditions (defined as a minimum 48-hour antecedent period without precipitation) for analysis of PCBs and (in 1988 only) conductivity and total suspended solids.

Various methods of estimating or measuring stormwater flow rates were used. The most reliable flow data are those collected in 1988 as part of the Peterborough Pollution Control Plan (PPCP), a joint MOE-City of Peterborough study primarily investigating bacterial contamination of the City's public bathing beaches. For the PPCP study, continuous, electronic water level data loggers were installed in a number of locations, including the same two locations in the Rink Street and Park Street storm sewer systems sampled for PCBs.

An urban stormwater computer simulation model was also developed for the PPCP study (Theil and Beak 1989). Potentially, output from this model could be used to estimate the PCB loads generated from the Rink Street and Park Street storm sewer systems.

2.2 Monitoring of Receiving Waters

2.2.1 Provincial Water Quality Monitoring Network

There are eight Provincial water quality monitoring stations within the study area between the inlet to Katchewanooka Lake and the outlet of Rice Lake at Hastings. In 1985, water samples for PCB analysis were collected monthly from February to May inclusive at each of these stations. These data were intended to establish the concentrations of PCB in receiving waters upstream and downstream of Peterborough.

2.2.2 Sediment Sampling

To ascertain the spatial distribution of PCB-contaminated sediments in receiving waters, an Ekman grab was used to collect samples of surficial sediment for PCB analysis from a number of locations within Little Lake, the Otonabee River and Rice Lake. In addition, a limited number of sediment cores were collected using a brass core sampler. These cores were sectioned vertically prior to analysis to obtain a historical perspective of PCB contaminant inputs. Sediment samples were also analysed for total organic carbon (TOC) to determine if the concentrations of TOC and PCB were interrelated.

2.3 Biomonitoring

2.3.1 Sport Fish

PCB levels in sport fish were determined as part of the Sport Fish Contaminant Monitoring Program. This program has operated Province-wide since 1976 as a co-operative undertaking of the MOE and the Ministry of Natural Resources (MNR), with results published annually in the "Guide to Eating Ontario Sport Fish" (MOE and MNR 1990). Fish are collected by the MNR; skinless, boneless fillets of dorsal muscle are analysed for contaminants by the MOE. In the Peterborough area, data are available for several fish species from the following locations:

- Otonabee River north of Trent University (upstream of Peterborough);
- Otonabee River at Little Lake;
- Otonabee River between Highway 7 and Rice Lake;
- Rice Lake off the Otonabee River;
- Rice Lake at the eastern end.

2.3.2 Young-Of-The-Year Yellow Perch

Since the discovery of elevated PCB levels in rock bass from Rice Lake in 1976, young-of-the-year yellow perch have been collected from Rice Lake and the Otonabee River to assess temporal and spatial trends of PCB availablity. The use of young-of-the-year yellow perch as biomonitors offers a data base that reflects time-integrated changes in water quality and PCB availability. Juvenile yellow perch feed on zooplankton and immature aquatic insects and are themselves an integral part of the

forage base for predatory fish and waterfowl (Scott and Crossman 1973). As such, they provide an important pathway of contaminant transfer to higher trophic levels.

Fish were collected with a 0.6-cm-mesh bag seine, frozen using dry ice in the field and kept at -10°C until analysed.

2.3.3 Mussels

In mussel biomonitoring studies, uncontaminated mussels are placed in areas suspected of being contaminated. Mussels filter large volumes of water and rapidly concentrate contaminants, such as PCBs, in their tissues and achieve equilibrium with the environment in a short period of time. Previous studies indicate that for PCBs, mussels will approach equilibrium with the environment within three weeks.

Mussel biomonitoring studies have not been used to quantify a discharge, however, they can be used to pin-point sources of contaminants and, semi-quantitatively, to compare biological availability of contaminants both spatially and temporally.

Mussel biomonitoring surveys were conducted in the study area in 1985 (2 surveys), 1986, 1987, and 1989. The purpose of the first survey was to identify the sources contributing to the elevated levels of PCBs observed in young fish and carp. Subsequent surveys were conducted to assess the extent of PCB contamination in the Otonabee River and Rice Lake and to determine the effectiveness of the remedial measures taken after the initial identification of sources.

The following methods were used in all of the surveys. *Elliptio complanata* (Lightfoot) with a maximum shell length of 65 to 72 mm were collected from Balsam Lake. This is a well-buffered lake which lies on the Trent-Severn Waterway in an area of Palaeozoic limestones. Concentrations of organochlorine contaminants, including PCBs, in mussels from Balsam Lake are low (Kauss and Hamdy 1985).

Immediately after collection, mussels were transported live, in bags of lake water, to the study area. At each monitoring station, five mussels were placed in a cage constructed of galvanized 1.25-cm-mesh poultry netting. The cage was anchored to the bottom so that the mussels were in contact with the sediment.

After an exposure period of three weeks, individual mussels were retreived, shucked and the soft tissues wrapped in hexane-rinsed aluminum foil and immediately placed on ice. The tissues were frozen within several hours of collection until analysed.

For each station, the soft tissues of three mussels were analysed individually for PCBs. The results are reported on a wet-weight basis.

2.4 Laboratory Analysis

All analyses were performed at the MOE laboratory in Toronto. Detailed analytical methods are described in MOE (1983). Analytical detection limits for PCB in the various types of samples employed in this study are as follows:

- Water/Sewage 20 ng/L;
- Sediment 0.020 μg/g (dry weight);
- Biological Tissue 20 ng/g (wet weight).

2.5 Data Analysis

For the mussel biomonitoring surveys, spatial and temporal differences in PCB levels were determined statistically using one-way ANOVA. If the ANOVA indicated that there were significant differences ($p < 0.05$) in PCB concentrations among stations, a Tukey's Honestly Significant Difference (HSD) test (Steel and Torrie 1960) was used to group stations with similar contaminant levels. Stations where the PCB levels were less than the detection limit of 20 ng/g were not used in the statistical analysis and were considered to represent a group of stations having similar contaminant levels significantly lower than other stations.

Analytical results of the study were interpreted relative to applicable Objectives and Guidelines as outlined in Table 2.1.

3.0 RESULTS AND DISCUSSION

3.1 Sewage Treatment Plant

Twenty-two of the 53 samples of influent raw sewage had detectable concentrations of PCBs (Table 3.1). Of these, the highest PCB level was 1970 ng/L recorded in October, 1988. Of the final effluent samples, only three had detectable PCB concentrations; PCB concentrations of 30 ng/L, 70 ng/L and 210 ng/L were recorded in samples collected in October, 1987, April, 1988 and August, 1988, respectively. PCB removal efficiencies were calculated for those samples with detectable PCB concentrations in the influent raw sewage. Removal efficiencies ranged from >67% to >99% and averaged >85%. These are likely underestimates of the actual removal efficiencies because, for calculation purposes, the non-detectable effluent concentrations were assumed to be the detection limit value of 20 ng/L. The two higher volume final effluent samples collected allowed the analytical detection limit to be lowered below 20 ng/L. Effluent PCB concentrations were 9 ng/L and <7 ng/L, respectively, for the September, 1987 and July, 1988 samples. For the September, 1987 sample, the influent PCB concentration of 240 ng/L was reduced to 9 ng/L in the effluent, a PCB removal efficiency of 96%. These data indicate that the wastewater treatment process effectively reduces the PCB levels of the sewage.

In a survey of wastewater treatment plants in southern Ontario, Shannon *et al.* (1976) found that plants with secondary treatment averaged 66% PCB removal efficiency. This removal was attributed primarily to physical separation by settling, with PCBs accumulating in the sludges. These authors note that, in some cases, this can pose potential sludge disposal problems, particularly if land disposal of sludges is practiced. Digested sludge from the Peterborough STP is trucked to farmland for disposal (MOE 1988). Presently there are no PCB guidelines for the agricultural use of sewage sludges (OMAF *et al.* 1986).

The Peterborough STP was one of the plants included in the survey by Shannon *et al.* (1976). These authors found that the influent PCB concentration at the Peterborough STP was 1000 ng/L, while the effluent concentration was < 100 ng/L, the analytical detection limit of their survey. This influent PCB level is within the range of those recorded in the present study.

With respect to PCB loading to the Otonabee River, based on mean annual average daily flow estimates for the STP of 54,140 m^3/day (MOE 1988) and a final effluent PCB concentration typically between zero and 20 ng/L, the annual PCB load from

the STP is estimated at between zero and 0.4 kg. As a whole, the sanitary sewage system may contribute a higher PCB load than this, however, due to the operation of sanitary sewer overflows and pumping station bypasses during periods of high inflow. There are 18 sanitary sewer overflows/bypasses in the City of Peterborough. In 1987 and 1988, these operated a total of 20 times; no estimates of discharge volumes are available (Theil and Beak 1989). The contribution of these in terms of PCB load was not assessed in the present study.

3.2 Catch-Basin Sediment

PCB concentrations in the 34 sediment samples collected from catch basins within the City ranged from less than detection (<0.020 μg/g) up to 7.6 μg/g. This wide range of concentrations suggests that PCB inputs are not uniform throughout the City, but rather that there exist in some areas sources of PCB to the storm sewer system which result in higher sediment PCB levels. Locations within the Park Street and Rink Street storm sewer systems typically had the highest PCB concentrations despite the coarse granular nature of the catch-basin sediments in those areas.

3.3 Stormwater Sampling

The initial extensive areal survey of stormwater runoff within the City in 1985 and 1986 showed that PCB concentrations in stormwater ranged from non-detectable (<20 ng/L) up to 5860 ng/L.

More intensive sampling carried out at several locations confirmed the CGE property as a significant source of PCB-contaminated runoff to the Rink Street storm sewer system. Samples were collected from a 46-cm-diameter pipe which discharges stormwater from the CGE property to the Rink Street storm sewer system at the intersection of Rink and Park Streets. On October 19, 1984 seven samples were collected during a storm event, with PCB concentrations ranging from 80 ng/L to 75000 ng/L. Sixteen samples were collected at this same location October 18, 1985 during another storm event. Concentrations of PCB ranged from 300 ng/L to 29900 ng/L. Samples collected at the same time from this pipe further up-gradient on CGE property had PCB concentrations which ranged from 70 ng/L to 19000 ng/L. Other suspected inputs to the Rink Street sewer system that were sampled had lower PCB concentrations.

Similar efforts to isolate sources were undertaken in the Park Street storm sewer system, with stormwater samples collected November 19, 1985. Although PCB concentrations were generally elevated downstream of the OMC/Peterborough Lumber properties, this sampling failed to conclusively identify single source areas. Ultimately, the monitoring locations were reduced to Rink Street at Stewart Street and Park Street at the outfall to the Otonabee River (Figure 2.1). The results of sampling at these locations are discussed in the following.

A summary of the dry weather sampling is presented in Table 3.2. PCB concentrations were similar at the two sampling sites; median concentrations were 60 ng/L and 100 ng/L at the Rink Street and Park Street sites, respectively. Total suspended solids concentrations were relatively low (maximum 16 mg/L), suggesting that sediment loads are low during dry weather.

Nine storm events were sampled in the Rink Street system from the location at Rink and Stewart Streets. PCB concentrations ranged from <20 ng/L to 14500 ng/L in the 99 samples collected. In the Park Street system, ten storms were sampled at the outfall to the Otonabee River. Here, PCB concentrations in the 103 samples collected ranged from <20 ng/L to 62500 ng/L. A summary of storm event sampling from Rink Street and Park Street is given in Table 3.3.

The concentration of PCBs in stormwater runoff was directly related to the concentration of total suspended solids (TSS) (Figure 3.1). This is not surprising, given the affinity of PCBs for sediment (Karickhoff *et al.* 1979). No similar relationship between PCB concentrations and conductivity levels was apparent.

3.4 Provincial Water Quality Monitoring Network

There were no detectable concentrations of PCBs in any of the water samples collected from the receiving waters from February to May 1985. The large discharge volume of the Otonabee River provides considerable dilution for the PCB inputs from land-based sources. There is no doubt that transport of PCB-contaminated material downstream occurs, however, its magnitude is difficult to quantify from the present data. The relation of the PCB concentrations in receiving waters to the Provincial Water Quality Objective (PWQO) for PCB is likewise difficult to assess, because the analytical detection limit for the PCB analysis is greater than the PWQO.

An effort was made, however, to obtain some helpful information in this regard. On April 13, 1987, during the spring freshet (daily mean flow of Otonabee River =

234.1 m^3/s), a centrifuge was used to extract suspended sediment from the Otonabee River water at the outlet of Little Lake near Trent-Severn Waterway Lock 19. Because the centrifuge was operated for 7.5 hours, the PCB concentration of the suspended sediment essentially represents an average condition for that time period. The corresponding average concentration of total suspended solids in the Otonabee River was determined by a series of five grab samples collected at regular intervals throughout the period of centrifuge operation.

The PCB concentration of the suspended sediment was 0.14 $\mu g/g$. The mean concentration of total suspended solids was 4.6 mg/L. PCBs were non-detectable (<20 ng/L) in grab water samples collected from the River. From these data, the PCB concentration of the suspended sediment phase of the Otonabee River water can be calculated as 0.64 ng/L, below the PWQO of 1 ng/L. Note, however, that McCrea *et al.* (1985) present evidence that this centrifuge method may greatly underestimate the actual PCB concentration. In their study in the lower Great Lakes region, a high proportion (up to 96%) of total PCBs was found to bypass the centrifuge in an "aqueous phase". Similarly, Chevreuil *et al.* (1987) found that 84% of the total PCBs was found in the water fraction. These latter authors speculate that, in the absence of a great amount of suspended matter, most of the PCBs are linked to the fluid phase. Therefore, we should consider our calculated PCB concentration for the Otonabee River to be an underestimate.

3.5 Sediment Sampling

Persaud *et al.* (1992) developed Provincial Sediment Quality Guidelines for use in evaluating aquatic sediments in Ontario. These are biologically based guidelines derived specifically to protect benthic organisms and to protect against the biomagnification of contaminants through the food chain. Using these guidelines, sediments can be classified relative to three effect levels: a No-Effect Level, a Lowest Effect Level, and a Severe Effect Level. Sediments with contaminant concentrations below the No-Effect Level are considered clean and are not expected to adversely impact water quality or benthic organisms. At contaminant concentrations between the No-Effect and Lowest Effect Levels, some sensitive water uses may be affected. Between the Lowest Effect and Severe Effect Levels, sediment use by some benthic organisms will be affected. Sediments with contaminant concentrations above the Severe Effect Level are considered grossly polluted; the use of these sediments by benthic organisms is expected to be significantly affected. For organic compounds, including PCBs, the Severe Effect Level guidelines are based on the organic carbon content of the sediments. Therefore, to compare the PCB

concentration of a given sample with the Severe Effect Level guideline, the guideline value must be converted to a bulk sediment value by adjusting for the TOC content of that sample.

Within the City of Peterborough, the area in Little Lake off the Rink Street storm sewer outfall was found to have the highest sediment PCB concentration (Figure 3.2). The maximum PCB concentration was 24.7 μg/g in a sample with 1.7% TOC; the corresponding Severe Effect Level guideline for this TOC content is 9 μg/g. This was the only location throughout the study area at which sediment PCB concentrations exceeded the Severe Effect Level. Virtually all other sediment samples collected as part of this study had sediment PCB concentrations between the Lowest Effect (0.07 μg/g) and Severe Effect Levels, indicating a marginal to significant degree of contamination. The only exceptions were those samples, one from the Otonabee River, two from the eastern end of Rice Lake, and a sediment core from the mouth of the Indian River, that had non-detectable sediment PCB concentrations. Note that the analytical detection limit for this study (0.020 μg/g) is below the Lowest Effect Level but above the No-Effect Level (0.01 μg/g).

The high sediment PCB concentrations in the granular sediment close to the Rink Street storm sewer outfall suggest the presence of an active source of PCB contamination. Immediately upstream near the mouth of Jackson Creek, samples of similar granular sediment had low PCB concentrations as would be expected in the absence of an active source (Figure 3.2). High PCB concentrations were also found in the Little Lake depositional area in association with the fine-grained, organic sediments here. Intermediate concentrations were noted at other sites within the lake where sediments were moderately organic, sandy-silt. There was no positive relationship between sediment PCB and TOC in Little Lake.

Erosion and transport of contaminated sediment from Little Lake may provide a source of PCB contamination to the lower Otonabee River and Rice Lake. In our centrifugation work, described previously, the suspended sediments in water draining from Little Lake had a PCB concentration that exceeded the Lowest Effect Level. Ferguson and Metcalfe (1989) used the results of sediment core analysis to estimate the reservoir of PCBs in Little Lake. These authors estimate that there are 185 kg of PCB material in the depositional area of Little Lake. Of this, they consider 49 kg to be "active" and potentially available for downstream movement, although the actual amount of downstream transport has not been quantified. It should be noted that these historical deposits in Little Lake are not themselves an original source of PCBs. The spatial distribution of PCBs in Little Lake indicates that virtually all of the PCB material resident in the depositional zone entered and, in fact, continues to

enter the lake via the Rink Street and, to a lesser extent, the Romaine Street storm sewer systems.

The PCB levels of surficial sediments in the Otonabee River from Little Lake to Rice Lake varied from <0.020 μg/g to more than 5 μg/g (Table 3.4). The riverine sediment PCB concentrations were not related to organic content or sediment grain size. Low PCB concentrations were found in samples collected at tributary mouths not influenced directly by the main river flow, suggesting that the agricultural areas drained by these tributaries are not sources of PCB contamination.

The pattern of contamination in the main river channel suggests that an upstream supply of PCB-contaminated sediment was being carried by the river and that elevated PCB concentrations occurred only in those small sheltered areas where fine sediments from the main flow could accumulate. No additional sources downstream of the City of Peterborough were implicated.

At the mouth of the Otonabee River in Rice Lake, high PCB concentrations were noted in the fine-grained mud (Table 3.4). Further sampling of Rice Lake in 1986 confirmed elevated levels near the mouth of the Otonabee River and also showed generally decreased levels with distance from the River mouth (Figure 3.3). The Otonabee River appeared to be the only source of PCB contamination to Rice Lake. Ferguson and Metcalfe (1989) showed that the PCB congener patterns of sediment were similar at all sites sampled from Little Lake to Rice Lake, suggesting that the PCBs in Rice Lake originate in Peterborough, and that sediment transport is the primary mechanism for downstream PCB movement.

Analysis of sectioned sediment core samples from an undisturbed area of a lake can often provide helpful insight into the history of a contaminant problem. Suspended particulate matter present in the water column of lakes and rivers will settle to the bottom where water currents allow. If the area is sufficiently sheltered from disturbances which sweep away or redistribute the bed sediment then new layers of suspended sediment are continually laid down, creating a long-term record of particles carried in the water column above, including sediment-bound contaminants.

Core samples from the Little Lake depositional area indicated that elevated PCB concentrations extended into the sediment to at least a depth of 15 cm. At the deepest, most sheltered point in Little Lake the sediment had moderately high PCB concentrations near the surface, changing to a layer of higher concentrations beneath (Figure 3.4). This increase in PCB concentration with depth suggests that PCB loads to the overlying water are presently lower than they have been in the past.

Unfortunately, the core sample taken here was not deep enough to define the lower depth limit of PCB contamination. Ferguson and Metcalfe (1989) found that PCB contamination in the deep basin of Little Lake extended at least 30 cm below the sediment-water interface.

In 1985, Ferguson and Metcalfe (1989) collected several core samples from the Otonabee River downstream of Peterborough. In general, PCB concentrations in these core samples increased with depth to a peak concentration and then declined. Based on these results, recent PCB loadings to the Otonabee River appear lower than in the past.

It is interesting to note that a core sample from the mouth of the Indian River in Rice Lake had non-detectable total PCB concentrations throughout its depth. This finding supports the idea that the remnants of the former railroad causeway in Rice Lake may present a partial barrier to sediment movement.

3.6 Sport Fish

Results from the MOE's Sport Fish Contaminant Monitoring Program for Rice Lake off the Otonabee River are presented in Figure 3.5. Only carp have been found with PCB levels which exceed the 2000 ng/g Federal guideline; PCBs in walleye, yellow perch and largemouth bass have remained at lower levels throughout the period of record, 1977 to 1987. This greater degree of PCB accumulation in carp relative to other species is primarily due to a relatively higher fat content in carp tissue. Plots of PCB concentration versus fish length are quite similar for carp collected from Rice Lake in 1983, 1984, 1985, and 1987, indicating little change in the PCB levels of carp over this time period. The relationship between PCB concentration and fish length for carp is shown in Figure 3.6. Consumption restrictions are advised for larger carp (length >65 cm) from Rice Lake and the lower Otonabee River due to PCB levels over 2000 ng/g (MOE and MNR 1990).

Although still well below the Federal guideline, PCB concentrations in walleye collected from Rice Lake are considerably higher than in walleye from Buckhorn Lake or Sturgeon Lake, located upstream from Peterborough (Figure 3.7). PCB levels in walleye from the latter two lakes are more typical of areas not impacted by point sources of PCB contamination.

3.7 Young-Of-The-Year Yellow Perch

The spatial distribution of PCB residues in yellow perch collections demonstrates that, relative to the upstream control locations, PCB availability was considerably higher at all the Otonabee River sites sampled downstream from Trent University in Peterborough (Figure 3.8, Table 3.5). Within Rice Lake, the spatial distribution pattern shows that PCB enrichment from the Otonabee River occurs primarily in a southeasterly direction, as evidenced by residue levels in the Spook Island and Idylwilde Point collections. Enhanced PCB availability extends east as far as Seymour Lake, some 80 km downstream of Peterborough. No evidence of PCB enrichment was found in the lower Trent River collections near Trenton.

Yellow perch collections from Spook Island provide the most comprehensive data base for temporal trend assessment, with several distinct phases of PCB availability (Figure 3.8). PCB residues declined significantly ($p<0.01$) in 1980 from the 1977, 1978 and 1979 levels, continued at reduced levels in 1981 and 1984 and increased again significantly ($p<0.01$) in the 1985 perch samples. PCB residues declined significantly ($p<0.05$) in 1986 and again in the 1987 collections. PCB concentrations in 1988 were not significantly different ($p>0.05$) from the 1987 residue levels. In 1989 and 1990, PCB residues returned to levels observed in the early 1980s, significantly higher ($p<0.05$) than the 1987 collections.

PCB residue levels in the young-of-the-year yellow perch exceeded the IJC Aquatic Life Guideline (100 ng/g) at all sampling sites except at the control and the Trenton sites.

3.8 Mussels

The initial mussel biomonitoring studies (1985 and 1986) were undertaken to identify the major sources of PCBs in the vicinity of Peterborough. Later studies were undertaken to assess the spatial extent of PCB contamination in the Otonabee River drainage basin (1987) as well as the temporal changes resulting from remedial measures (1987 and 1989).

In the earlier studies the Rink Street, Romaine Street and Park Street storm sewers were identified as the major sources of PCBs to the Otonabee River (Figure 3.9). These studies also found that the bioavailability of PCBs to mussels declined rapidly with distance from source to near or below the analytical detection level immediately downstream of Peterborough. However, in the lower Otonabee River close to Rice

Lake, PCB bioavailability increased to levels not significantly different ($p<0.05$) from the levels found in Little Lake in the vicinity of the Romaine Street storm sewer (Figure 3.10).

Later surveys failed to identify additional sources of PCBs in the lower Otonabee River. It was concluded that contaminated sediments in the lower Otonabee River were acting as a source of PCBs. Studies by Koenig and Metcalfe (1990) found a similar pattern of elevated PCBs in the lower Otonabee River. Those authors undertook congener specific PCB analysis and found that lower chlorinated PCBs were proportionally higher in mussels in the lower Otonabee River compared to the upper river near Peterborough. They concluded that the lower chlorinated PCBs, which are more hydrophilic, were being released from the sediments and becoming biologically available.

In 1987, the most comprehensive mussel biomonitoring survey was undertaken in order to assess the spatial distribution of bioavailability of PCBs. Sites were monitored between Peterborough and the Bay of Quinte (Figure 3.11). The results of this study were consistent with previous ones. High PCB levels were found in mussels exposed at the three storm sewer sources in Peterborough and in the lower Otonabee River. Within Rice Lake, detectable levels (>20 ng/g) were found in mussels exposed near the mouth of the Otonabee River and in a north-easterly direction toward the outlet of the lake. In contrast, levels in the south-western end of the lake were below the analytical detection limit (Figure 3.10). In the Trent River downstream of Rice Lake, levels were also less than the analytical detection limit. In 1986 detectable levels had been found downstream at Seymour Lake.

These data, when interpreted with the findings of Koenig and Metcalfe (1990), strongly suggest that PCBs from sources in Peterborough have contaminated the sediments in the lower Otonabee River and in Rice Lake from the mouth of the Otonabee River north-easterly to the outlet of the lake. These sediments appear to be acting as a source of lower chlorinated PCBs to biota.

In 1989, a mussel biomonitoring study was undertaken in the immediate vicinity of the PCB sources with the primary purpose being to determine if remedial measures had been effective in reducing the loadings of PCBs to Little Lake and the Otonabee River (Figure 3.9). During the period of study (1985 to 1989), the concentrations of PCBs in mussels at the two sites near the Rink Street storm sewer have fluctuated significantly ($P<0.05$) between a low of 273 ng/g and a high of 1020 ng/g. However, no significant trend with time was evident. These data do not support the hypothesis that there has been a significant reduction in the discharge of PCBs, but

rather, suggest that the Rink Street storm sewer is still a major source of these contaminants to Little Lake.

During the study period, PCBs in mussels exposed near the Park Street storm sewer have steadily declined from a high of 1035 ng/g in 1985 to a low of 140 ng/g in 1989. This decline was significant ($P<0.05$) and strongly suggests that discharges of PCBs from this storm sewer have decreased.

During the period 1985 to 1987, PCBs in mussels exposed near the Romaine Street storm sewer increased from 47 ng/g to 267 ng/g but in 1989, concentrations were below the detection limit. Unlike the Rink Street and Park Street storm sewers, the Romaine Street storm sewer flows intermittently. The PCB levels found in mussel tissue therefore reflect both the frequency and duration of storm events during the mussel exposure period and the absolute quantities of PCBs that are discharged. The fact that the concentration in mussel tissue was below detection in 1989 may indicate that PCBs from this source have been controlled, although further studies are required to confirm this.

In summary, the mussel biomonitoring studies identified three primary sources of PCBs - the Rink Street, Park Street, and Romaine Street storm sewers. The data suggest that the quantity of PCBs being discharged from the latter two sources has declined. The concentration of PCBs in mussels in the lower Otonabee River are elevated. Detectable levels are also present throughout Rice Lake from the mouth of the Otonabee River, in a north-easterly direction to the outlet of the Lake. It appears that PCBs from the Peterborough area have contaminated the sediments in the lower Otonabee River and Rice Lake and are now acting as a source of lower chlorinated PCBs to biota.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

1. PCB loadings to the STP are effectively reduced by the wastewater treatment process, with PCBs accumulating in the sewage sludge.

2. Samples of catch-basin sediment and stormwater indicate that the highest PCB concentrations in storm sewers are in the Rink Street and Park Street storm sewer systems.

3. Caged mussel biomonitoring confirms that the Rink Street, Park Street and, to a lesser extent, the Romaine Street storm sewer systems are sources of PCBs. No other PCB sources upstream or downstream of Peterborough have been identified.

4. The CGE property is the primary source of PCB loading to the Rink Street storm sewer. The sources of PCB loading to the Park Street storm sewer are less clear, however, the former OMC and Peterborough Lumber properties are implicated.

5. The highest sediment PCB concentrations are found in Little Lake in the vicinity of the Rink Street storm sewer outfall. At this location, PCB concentrations exceeded the Severe Effect Level of the MOE's Provincial Sediment Quality Guidelines. Sediment PCB contamination originates in Peterborough and extends at least as far as Rice Lake.

6. Based on young-of-the-year yellow perch and caged mussel biomonitoring, enhanced PCB availability extends downstream from Little Lake in Peterborough to Rice Lake and throughout Rice Lake from the mouth of the Otonabee River primarily in a north-easterly direction as far as Seymour Lake, located 80 km downstream of Peterborough.

7. PCB levels in young-of-the-year yellow perch exceeded the IJC Aquatic Life Guideline of 100 ng/g at all sampling sites on the Otonabee River and Rice Lake, except for the control sites located upstream of Peterborough.

8. Consumption restrictions are advised for larger carp from Rice Lake and the lower Otonabee River due to tissue PCB concentrations over the Federal

guideline of 2000 ng/g. Other species of sport fish tested have tissue PCB levels well below the Federal guideline, but above levels found in fish from two neighbouring lakes.

9. PCBs in the Otonabee River water are at concentrations lower than the analytical detection limit of 20 ng/L. Using centrifugation sampling, we have estimated that the PCB concentration of the Otonabee River water may be below the Provincial Water Quality Objective of 1 ng/L, however, based on results from similar studies, this is likely an underestimate.

10. Analyses of sediment cores suggest that PCB inputs are lower now than they have been in the past. PCB levels in young-of-the-year yellow perch collected off Spook Island in Rice Lake have fluctuated considerably over time; tissue PCB levels reached a maximum in 1985 and have since returned to lower levels. Mussel biomonitoring data suggest that the quantity of PCBs being discharged from the Park Street and Romaine Street storm sewers declined between 1985 and 1989. There was no evidence of a similar decline for the Rink Street storm sewer.

4.2 Recommendations

It is recommended that the MOE:

1. Continue to pursue abatement action directed at reducing PCB discharges from the Rink Street and Park Street storm sewer systems.

2. Establish a long-term biomonitoring program to assess the effectiveness of abatement measures in terms of improved receiving water quality and to continue temporal trend analysis.

3. Review all dredging, marine construction, and shoreline alteration projects proposed for Little Lake with respect to sediment quality, impacts on water circulation and sediment resuspension, and dredged spoils disposal locations.

4. Review the City of Peterborough's sewage sludge disposal practices.

5. Establish a Working Group to oversee abatement, monitoring, research and reporting activities related to PCBs in the Peterborough area.

LITERATURE CITED

CCREM (Canadian Council of Resource and Environmental Ministers). 1987. Canadian water quality guidelines.

Chevreuil, M., A. Chesterikoff and R. Letolle. 1987. PCB pollution behaviour in the River Seine. Wat. Res. 21:427-434.

Eisler, R. 1986. Polychlorinated biphenyl hazards to fish, wildlife and invertebrates: a synoptic review. U.S. Department of the Interior, Fish and Wildlife Service, Biological Report 85(1.7), Contaminant Hazard Reviews Report No. 7.

Ferguson, M.L. and C.D. Metcalfe. 1989. Distribution of PCB congeners in sediments of the Otonabee River-Rice Lake system, Peterborough, Canada. Chemosphere 19:1321-1328.

IJC (International Joint Commission). 1977. New and revised Great Lakes water quality objectives, Volume 2.

Karickhoff, S.W., D.S. Brown and T.A. Scott. 1979. Sorption of hydrophobic pollutants on natural sediments. Wat. Res. 13:241-248.

Kauss, P.B. and Y.S. Hamdy. 1985. Biological monitoring of organochlorine contaminants in the St. Clair and Detroit Rivers using introduced clams, *Elliptio complanata*. J. Great Lakes Res. 11:247-263.

Koenig, B.G. and C.D. Metcalfe. 1990. The distribution of PCB congeners in bivalves, *Elliptio complanata*, introduced into the Otonabee River, Peterborough, Ontario. Chemosphere 21:1441-1449.

MacLaren Plansearch. 1989. Little Lake and Otonabee River - Water movement study. Report to the City of Peterborough. Peterborough Pollution Control Plan.

McCrea, R.C., J.D. Fischer and K.W. Kuntz. 1985. Distribution of organochlorine pesticides and PCBs between aqueous and suspended sediment phases in the lower Great Lakes region. Water Poll. Res. J. Canada 20:67-78.

MOE (Ministry of the Environment). 1979. Rationale for the establishment of Ontario's Provincial Water Quality Objectives.

MOE (Ministry of the Environment). 1983. Handbook of analytical methods for environmental samples.

MOE (Ministry of the Environment). 1984a. Preliminary hearing document on proposals for the regulation of mobile PCB destruction facilities in Ontario.

MOE (Ministry of the Environment). 1984b. Water management goals, policies, objectives and implementation procedures of the Ministry of the Environment, Ontario. (revised from 1978 edition).

MOE (Ministry of the Environment). 1988. Thirty seven municipal water pollution control plants - Pilot monitoring study, Volume II Appendix 'A', Individual plant reports. Prepared by Canviro Consultants.

MOE and MNR (Ministry of the Environment and Ministry of Natural Resources). 1990. Guide to eating Ontario sport fish. Fourteenth Edition.

Moore, J.W. and S. Ramamoorthy. 1984. Organic chemicals in natural waters - Applied monitoring and impact assessment. Springer-Verlag, New York, 289 pages.

Neely, W.B. 1983. Reactivity and environmental persistence of PCB isomers. pages 71-88 *In:* Physical behaviour of PCBs in the Great Lakes. D. Mackay, S. Paterson, S.J. Eisenreich and M.S. Simmons (eds.), Ann Arbor Science, Ann Arbor, Michigan.

OMAF (Ontario Ministry of Agriculture and Food), Ontario Ministry of the Environment and Ontario Ministry of Health. 1986. Guidelines for sewage sludge utilization on agricultural lands. 32 pages. (revised from 1978 edition).

Persaud, D., R. Jaagumagi and A. Hayton. 1992. Guidelines for the protection and management of aquatic sediment quality in Ontario. ISBN 0-7729-9248-7.

Roberts, J.R., D.W. Rodgers, J.R. Bailey and M.A. Rorke. 1978. Polychlorinated biphenyls: biological criteria for an assessment of their effects on environmental quality. National Research Council of Canada, Publication No. NRCC 16077.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bulletin 184.

Shannon, E.E., F.J. Ludwig and I. Valdmanis. 1976. Polychlorinated biphenyls (PCBs) in municipal wastewaters: an assessment of the problem in the Canadian Lower Great Lakes. Research Program for the Abatement of Municipal Pollution within the provisions of the Canada-Ontario Agreement on Great Lakes Water Quality. Research Report No. 49.

Shiu, W.Y., and D. Mackay. 1986. A critical review of aqueous solubilities, vapor pressures, Henry's law constants and octanol-water partition coefficients of the polychlorinated biphenyls. J. Phys. Chem. Ref. Data 15:911-929.

Steel, R.G.D. and J.H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Company Inc., New York, 481 pages.

Strachan, W.M.J. 1988. Polychlorinated biphenyls (PCBs) - fate and effects in the Canadian environment. Environment Canada Report EPS 4/HA/2.

Taylor, C. 1985. The hydrology of Peterborough and the Kawarthas. pages 63-75 *In:* Peterborough and the Kawarthas. P. Adams and C. Taylor (eds.), Heritage Publications, Peterborough, Ontario.

Theil and Beak (Paul Theil Associates Limited and Beak Consultants Limited). 1989. Urban stormwater source and river/beach model study - Final Report. Prepared for the City of Peterborough and the Ministry of the Environment. Peterborough Pollution Control Plan.

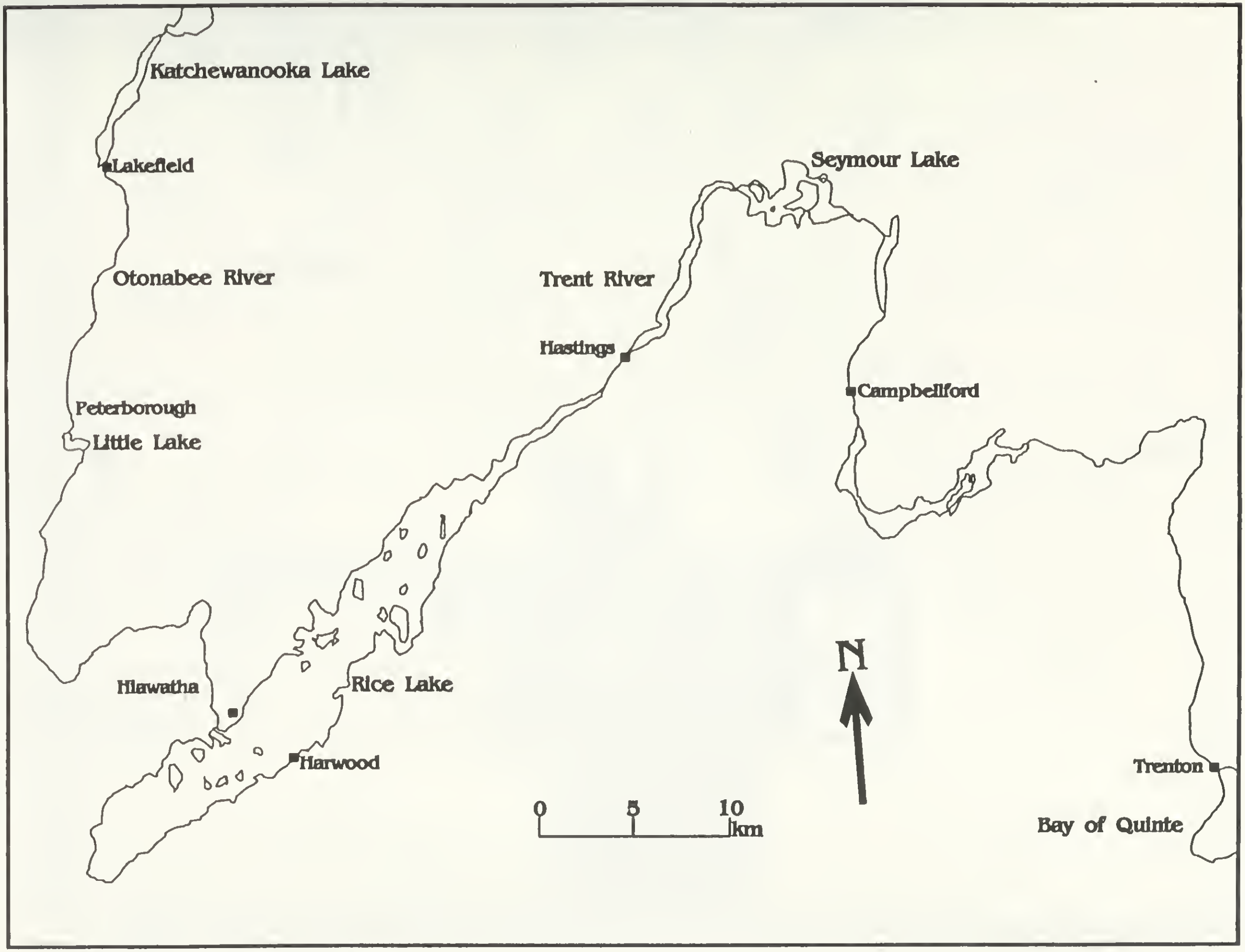


Figure 1.1 Study Area

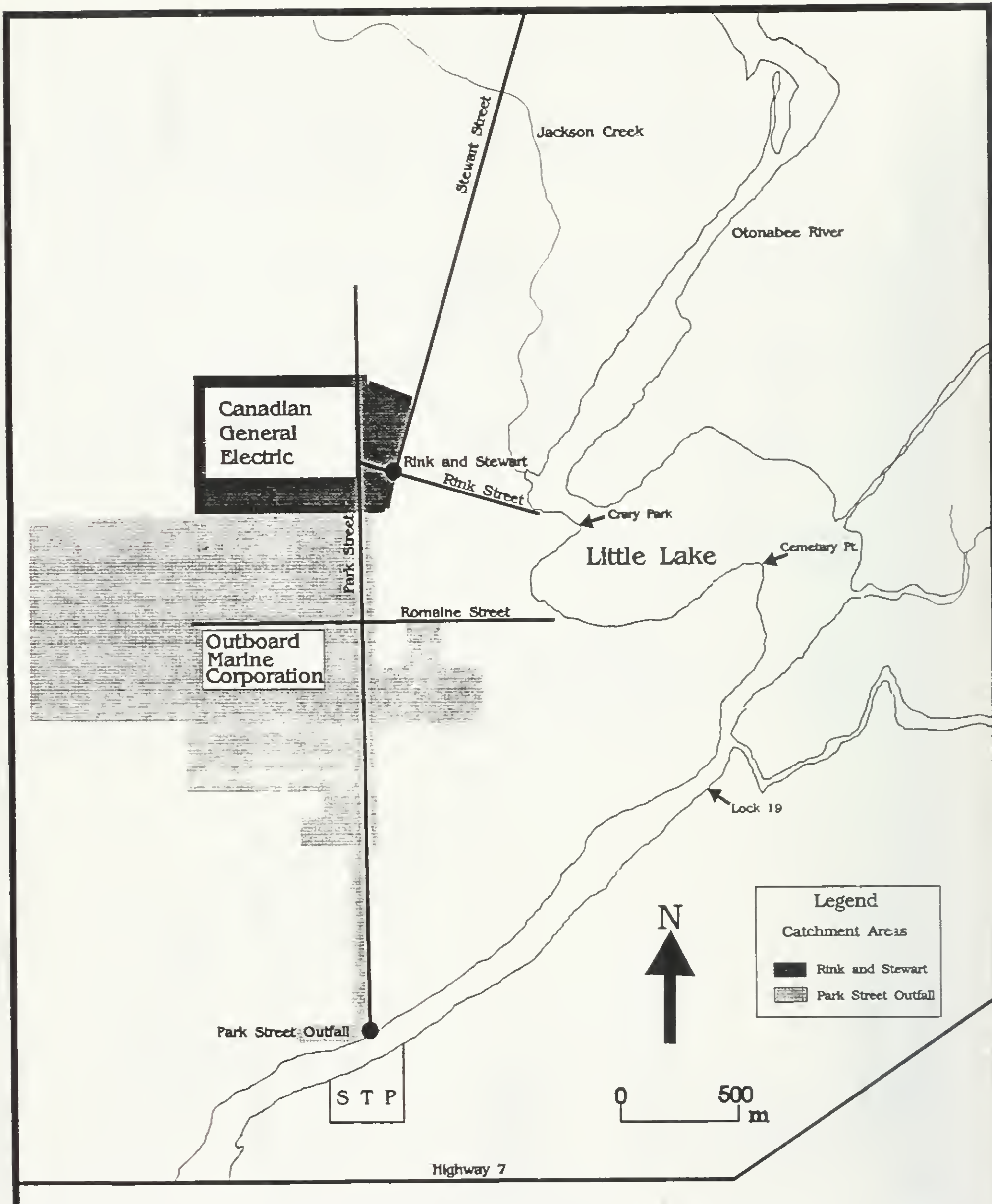
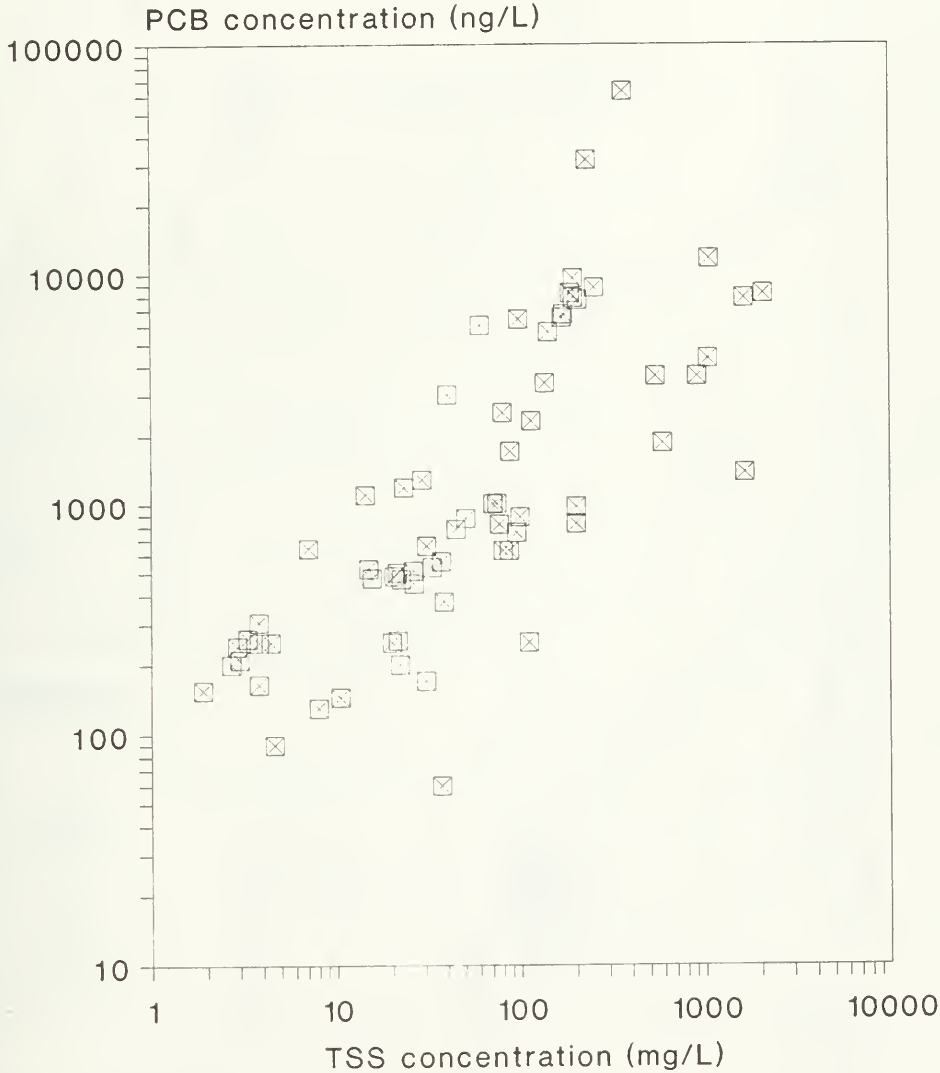


Figure 2.1 Stormwater sampling locations and approximate catchment areas for the Rink Street and Park Street storm sewer systems.

Figure 3.1 PCB and TSS in stormwater



log[PCB]=0.67(log[TSS])+1.88, r2=0.58

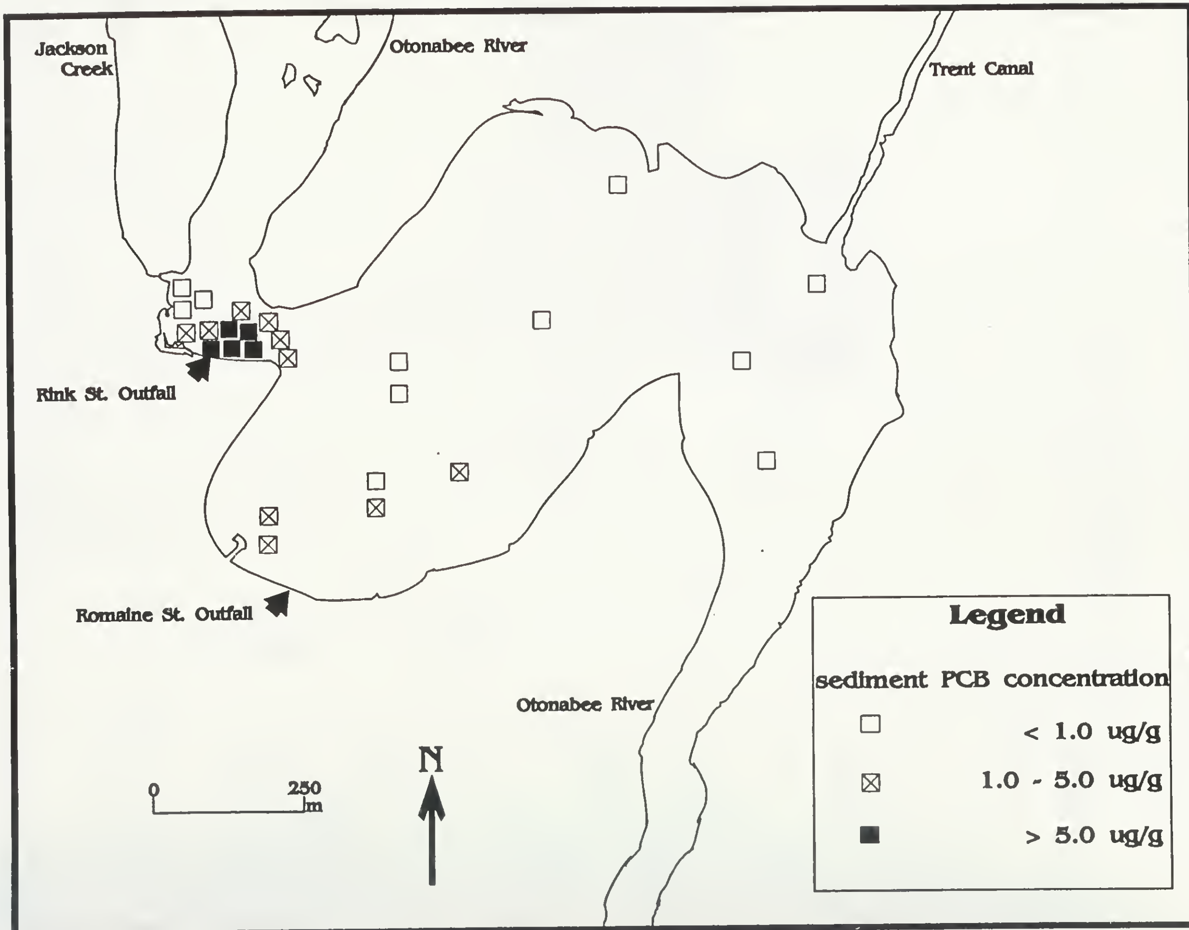


Figure 3.2 PCB concentrations in the surficial sediments of Little Lake.

Figure 3.3 Rice Lake Sediments
June, 1986

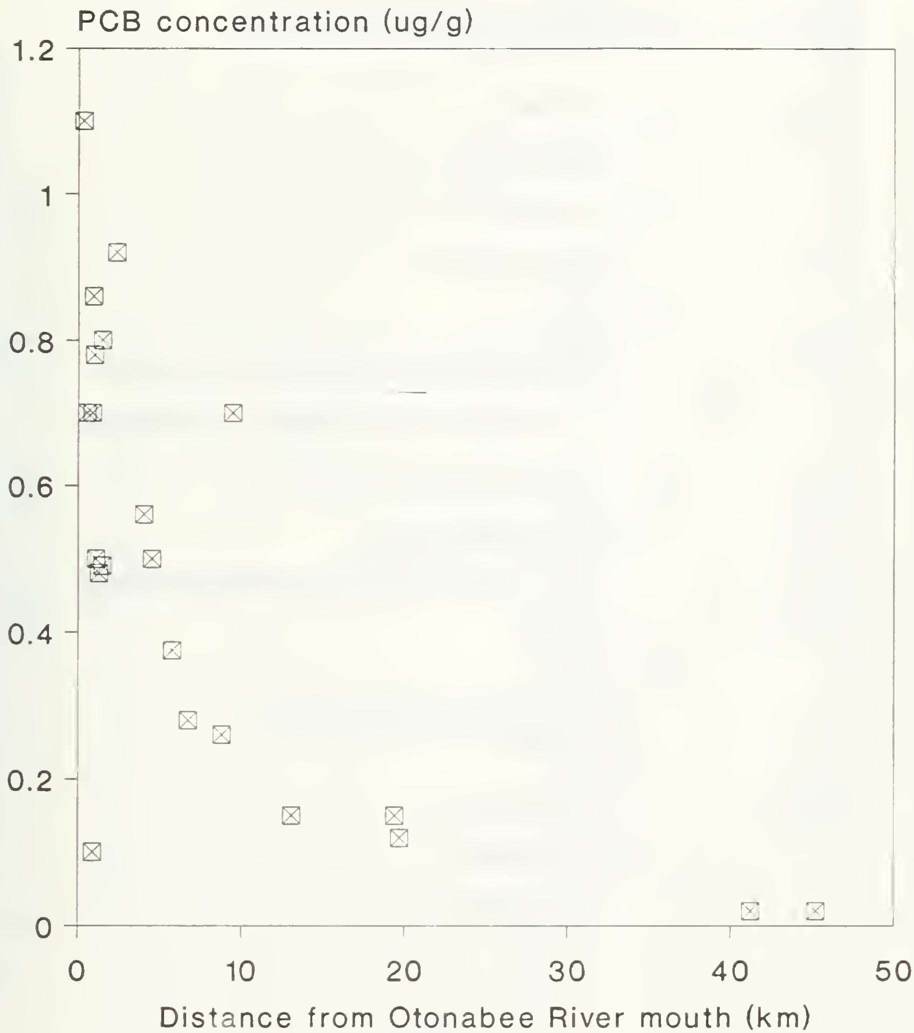


Figure 3.4 Sediment core from Little Lake, 1985

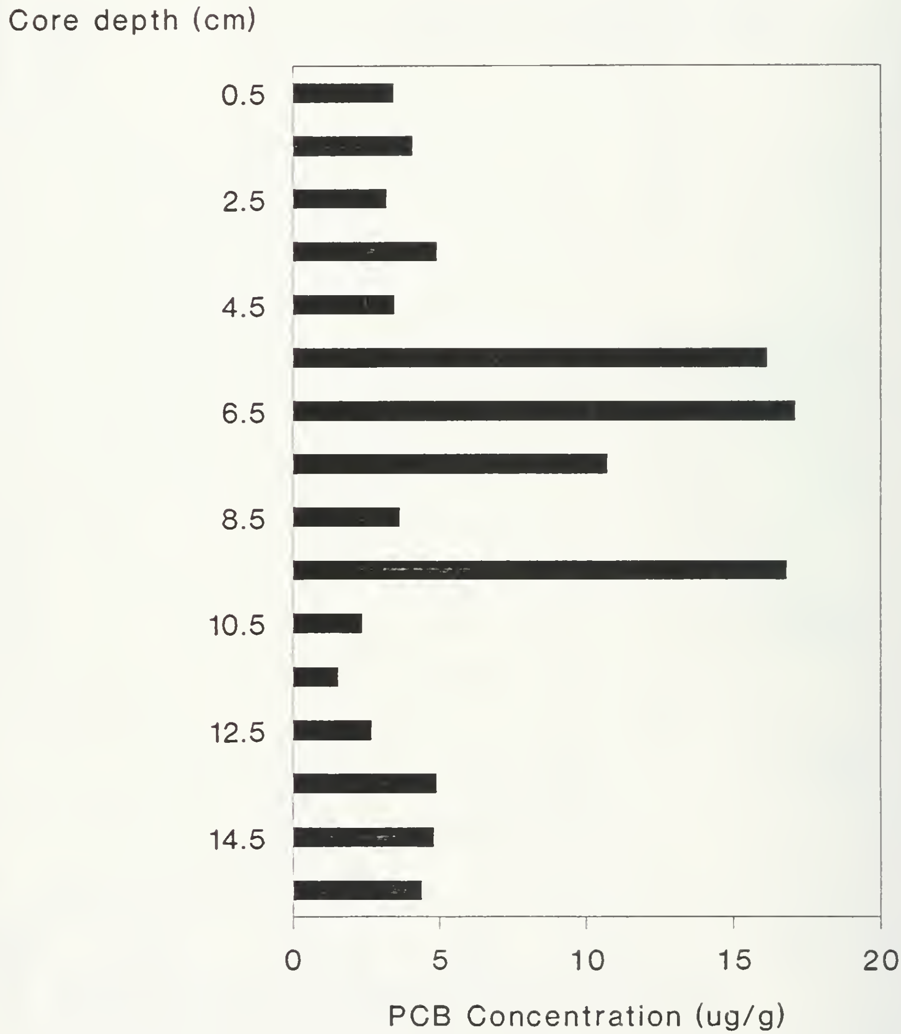


Figure 3.5 PCB Levels in Sport Fish
Rice Lake, 1977 to 1987

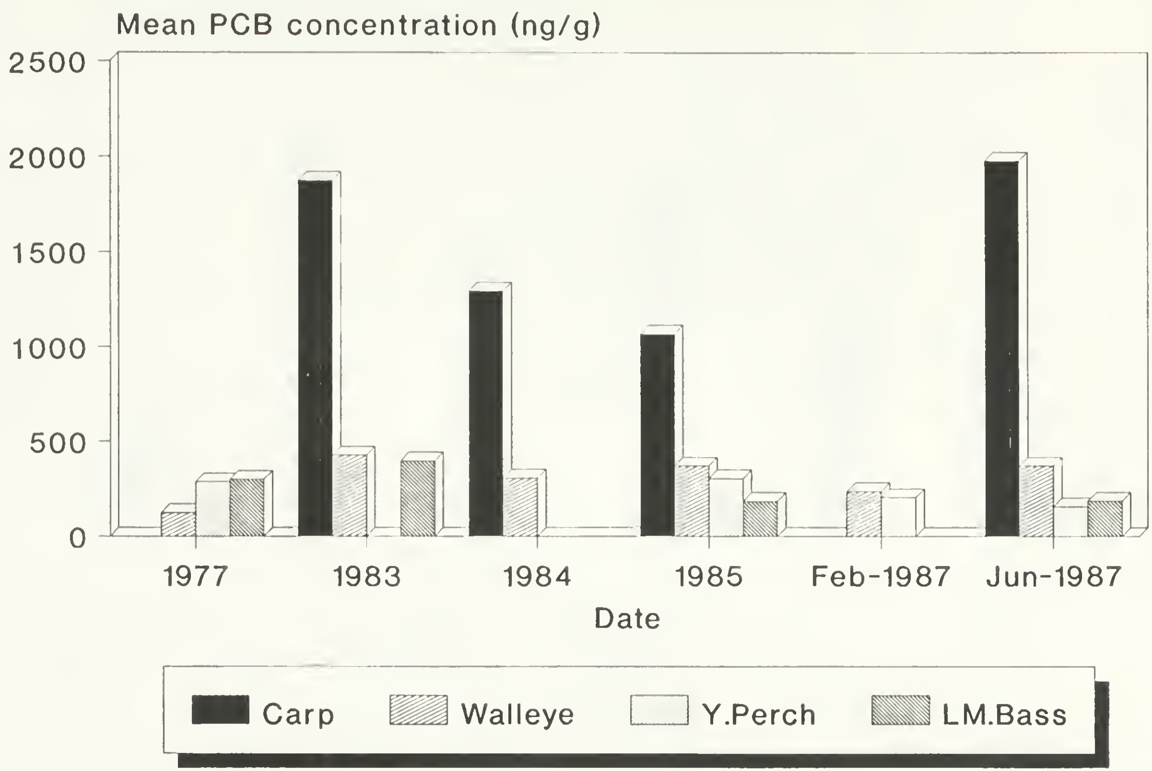


Figure 3.6 PCB vs length for carp from Rice Lake

log[PCB]=0.037(length)+0.72, r2=0.68

Figure 3.7 PCB Levels in Walleye
Rice, Buckhorn, & Sturgeon Lakes

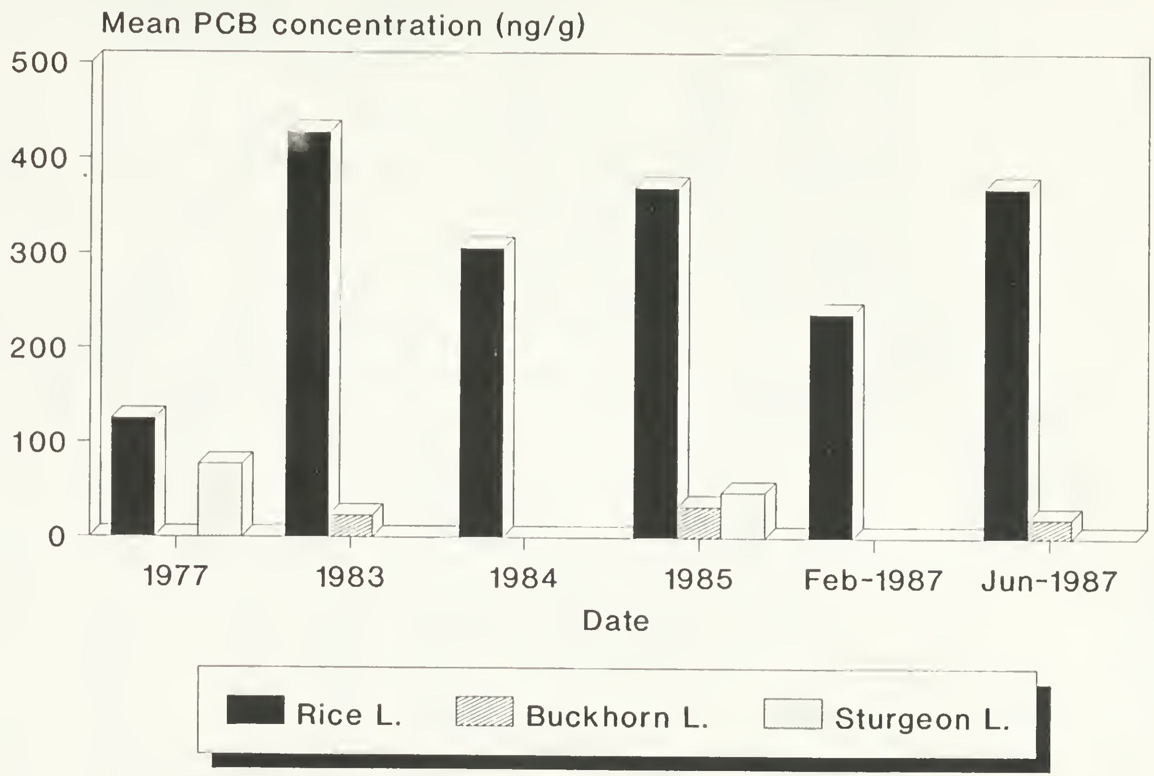


FIGURE 3.8 TOTAL PCB RESIDUE (ng/g) TRENDS IN YOUNG-OF-THE-YEAR YELLOW PERCH FROM THE OTONABEE RIVER AND RICE LAKE FROM 1977 TO 1990. VALUES ARE MEANS +/- 95% CONFIDENCE LIMITS.

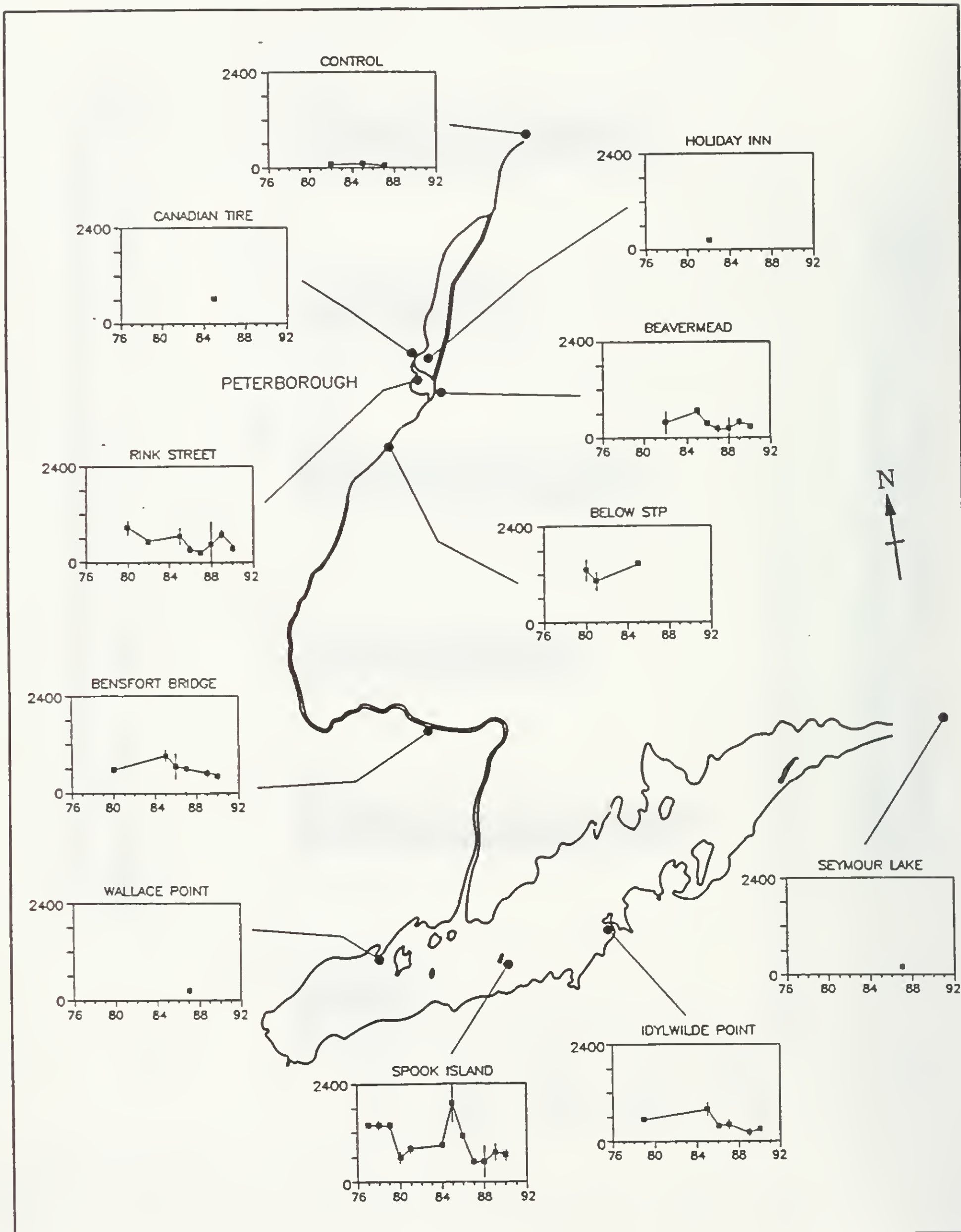


Figure 3.9 Mussel Biomonitoring Stations near Peterborough

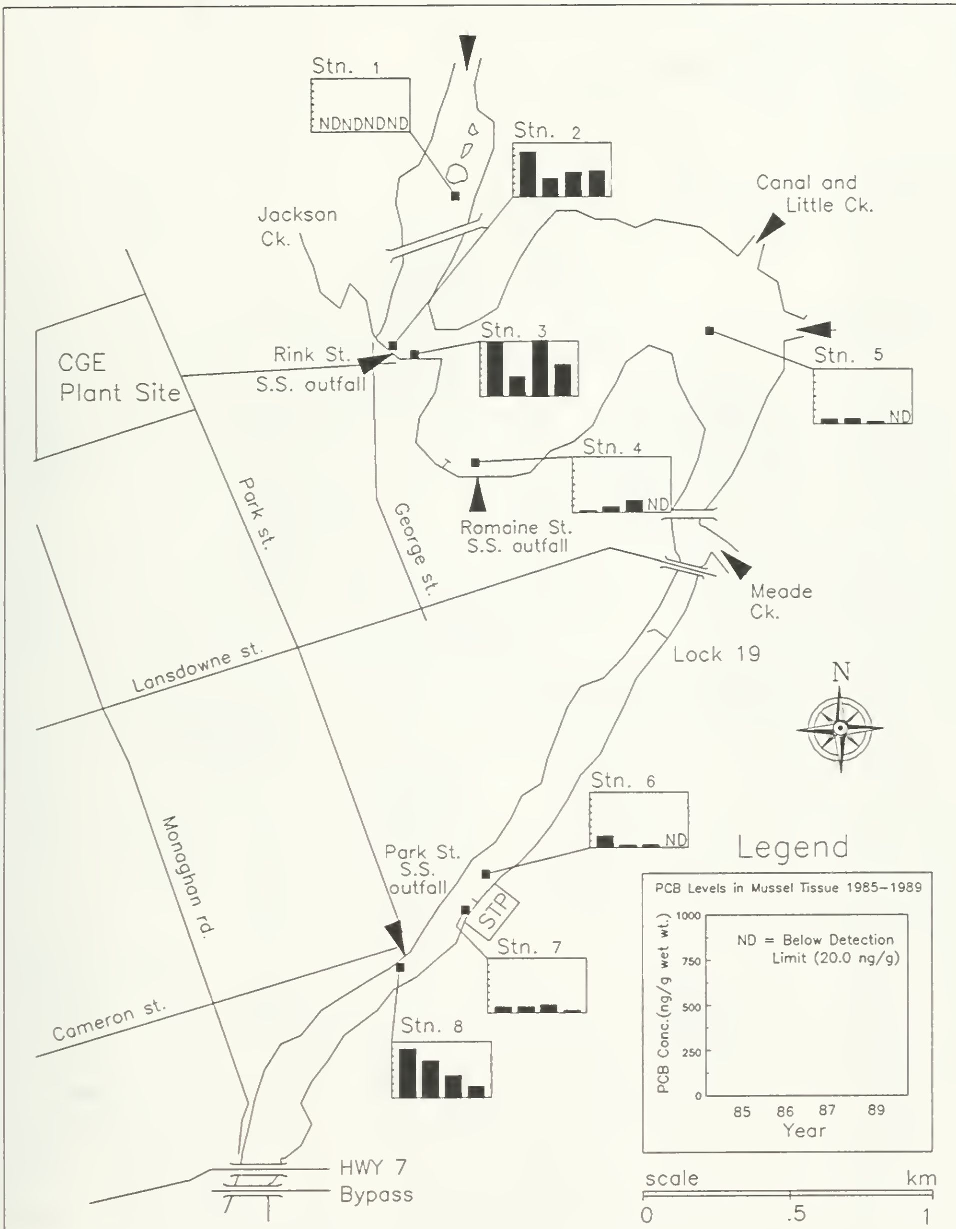


Figure 3.10 Mussel Biomonitoring Stations, Rice Lake

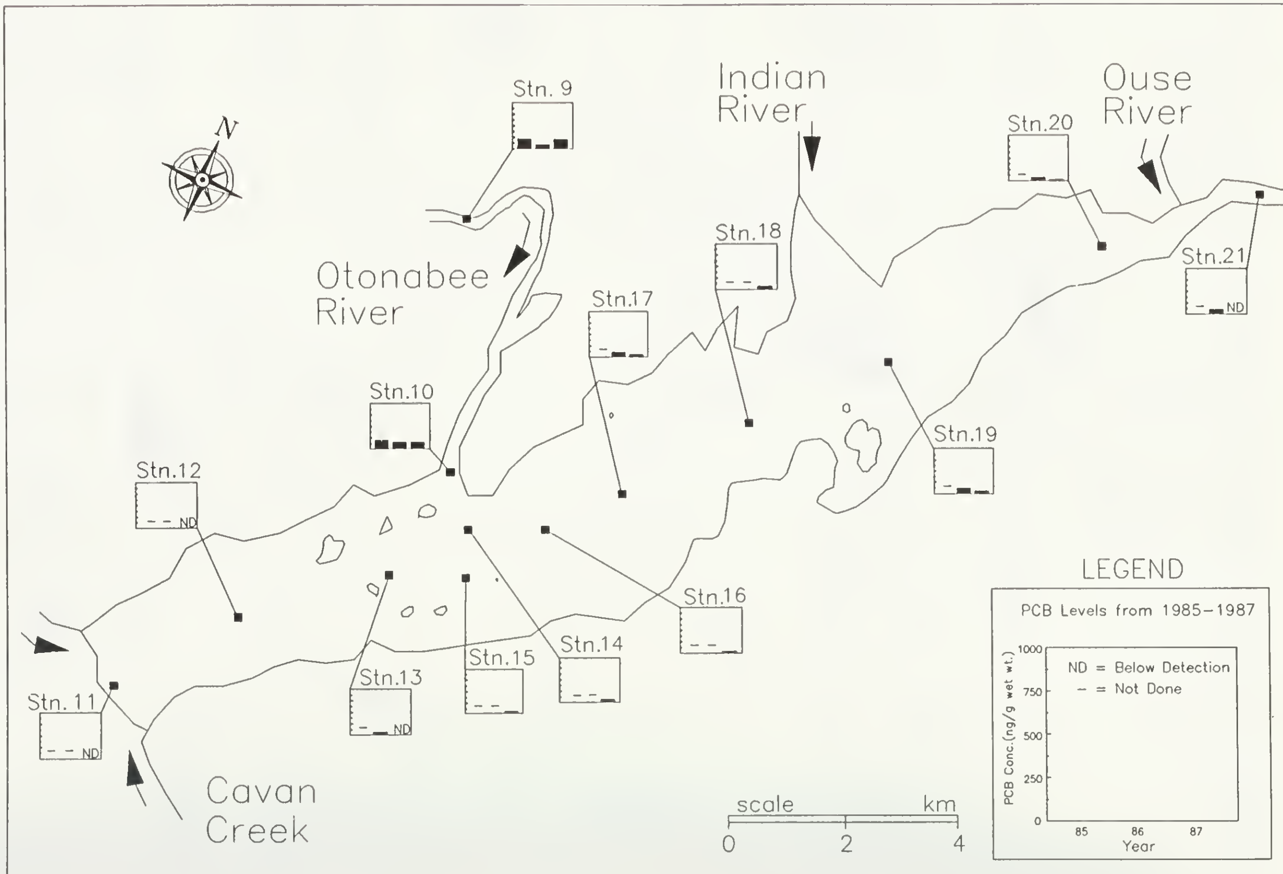


Figure 3.11 Mussel Biomonitoring Study Area

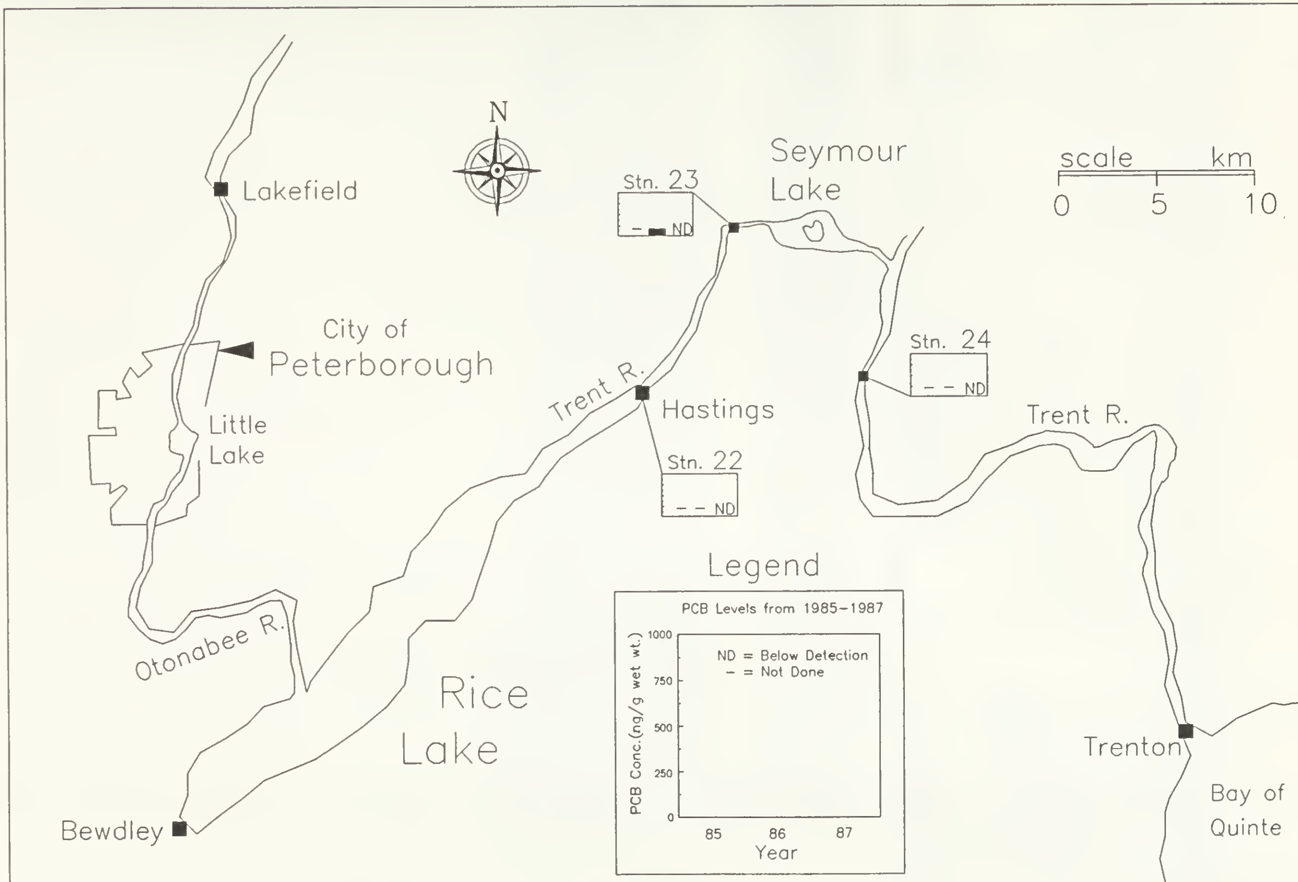


Table 2.1 Objectives and guidelines for PCBs.

Material	Objective/Guideline	Reference
surface water	1.0 ng/L[1]	MOE 1984b; CCREM 1987
sediment		Persaud *et al.* 1992
• no-effect level	0.01 μg/g dry weight	
• lowest effect level	0.07 μg/g dry weight	
• severe effect level	530 μg/g organic carbon[2]	
fish flesh	2000 ng/g wet weight	Health & Welfare Canada
juvenile fish	100 ng/g wet weight	IJC 1977

1 PCBs are defined by the MOE as having a "zero tolerance limit". The Objective specified is intended to provide guidance for dealing with past releases or accidental losses, but not for new releases; new discharges should be reduced to the lowest practicable levels (MOE 1984b).

2 Guideline value is converted to a bulk sediment value by multiplying by the actual TOC concentration of the sediments (to a maximum of 10%). For example, analysis of a sediment sample gave a PCB value of 30 μg/g and a TOC of 5%. The value for the Severe Effect Level is first converted to a bulk sediment value for a sediment with 5% TOC by multiplying 530 x 0.05 = 26.5 μg/g as the Severe Effect Level guideline for that sediment. The measured value of 30 μg/g is then compared with this bulk sediment value and is found to exceed the guideline.

Table 3.1 Summary of STP sampling

Year	raw sewage #samples	raw sewage detections[1]	final effluent #samples	final effluent detections[1]
1985	26	11	25	0
1986	7	4	7	0
1987	13	3	12	1
1988	7	4	9	2
Totals	53	22	53	3

[1] detection limit = 20 ng/L

Table 3.2 Summary of dry weather[1] sampling for Rink Street and Park Street storm sewer systems, 1987 and 1988.

Location	#samples	[PCB] ng/L minimum	[PCB] ng/L maximum	[PCB] ng/L median
Rink St.@ Stewart St.	41	<20	550	60
Park Street @ outfall	41	<20	330	100

[1] defined as a minimum 48-hour antecedent period without precipitation.

Table 3.3 Summary of storm event sampling for Rink Street and Park Street storm sewer systems.

Location	Date	Time of Sampling	# Samples	[PCB] ng/L minimum	[PCB] ng/L maximum	[PCB] ng/L median	Total Rainfall[1] (mm)
Rink Street	31-Jul-85	1354-1630	13	280	4490	450	2.2
@ Stewart	18-Oct-85	1530-2000	16	80	14500	325	9.8
	23-Aug-86	0840-1500	13	<20	<20	<20	2.8
	01-Nov-86	1500-1900	9	65	450	225	5.0
	27-Apr-87	1750-2345	13	<20	1310	460	12.4
	29-Sep-87	1815-2225	10	70	1300	290	2.6
	25-Jun-88	1000-1200	7	1100	11600	2300	8.4
	23-Aug-88	1910-2009	8	200	875	538	14.6
	13-Sep-88	0340-0525	10	155	1180	498	6.2
Park Street	31-Jul-85	1400-1630	14	170	3240	860	2.2
@ outfall	23-Aug-86	0850-1450	12	110	310	175	2.8
	01-Nov-86	1515-1915	9	190	330	290	5.0
	27-Apr-87	1750-2345	13	<20	12000	960	12.4
	29-Sep-87	1830-2230	10	40	630	100	2.6
	25-Jun-88	1000-1200	7	250	8200	1850	8.4
	23-Aug-88	1910-2050	8	60	62500	4050	14.6
	13-Sep-88	0349-0504	8	3000	9550	6562	6.2
	26-Sep-88	1850-2220	8	130	260	205	0.4
	15-Oct-88	1215-1815	13	90	8700	775	4.4

[1] Rainfall for the entire storm event as recorded at the Peterborough Airport by Environment Canada's Atmospheric Environment Service.

Table 3.4 PCB concentrations in surficial sediments of the Otonabee River and Rice Lake, June and August, 1985.

Landmark	Distance downstream (km)	June [PCB] $\mu g/g$	June % TOC	August [PCB] $\mu g/g$	August % TOC
Hwy. 7 Bypass	0.0			2.83	2.0
	3.2			2.54	3.3
	6.1			0.22	1.4
	7.4			0.08	2.0
	10.4			0.40	6.9
	10.6			2.82	9.1
Wallace Pt.	11.0	0.40	0.5		
(mid-channel)	14.1	0.18	0.6		
(off swamp)	14.1	5.16	1.3	2.90	16.0
	16.3			<0.02	1.1
	16.6			0.29	19.0
Bensfort Bridge	17.3				
	24.3			1.08	2.5
Otonabee mouth	29.4				
(R6)	29.9	2.24	1.0	0.26	1.2
(R1)	30.0	4.28		2.06	3.5
(R5)	30.3	10.22	7.0	3.82	1.6
(R2)	30.4	11.62	8.0	2.80	7.8
(R4)	30.7	1.24	1.0	4.37	12.0
(R3)	30.8	15.56	9.6	4.82	11.0

Table 3.5 PCB residues in juvenile yellow perch. Values shown are means ± one standard deviation.

Location	Year	length(mm)	N[1]	% lipid	PCB(ng/g)
Otonabee River					
Control above Trent University	1982	100±5	3	5.1±0.5	76±12
	1985	69±5	5	2.2±0.7	90±28
	1987	51±2	2	1.5±0.3	20±14
Upstream of Little Lake:					
- east bank	1982	77±4	4	4.4±0.6	224±31
- west bank	1985	68±4	4	2.7±1.1	620±35
Little Lake @ Rink Street	1980	89±5	6	4.5±0.4	865±149
	1982	72±3	4	4.2±0.4	524±40
	1985	71±2	5	2.6±0.8	657±146
	1986	64±5	5	2.3±0.2	312±67
	1987	52±5	5	1.7±0.3	244±36
	1988	68±2	3	2.8±0.3	440±270
	1989	64±2	5	3.3±0.4	700±84
	1990	63±3	6	2.4±0.4	346±62
Little Lake @ Beavermead Pk	1982	73±3	4	4.1±0.8	369±145
	1985	68±3	5	1.6±0.5	641±74
	1986	65±6	5	2.5±0.4	342±42
	1987	52±3	6	1.9±0.5	210±100
	1988	68±2	4	3.8±0.4	215±133
	1989	65±2	5	2.6±0.4	370±72
	1990	61±3	6	2.0±0.9	265±48
Below STP (Highway 7)	1980	82±2	6	4.5±0.3	1311±231
	1982	88±3	4	6.6±0.5	1034±121
	1985	72	2	2.8	1450
Bensfort Bridge	1980	72±2	6	3.1±0.3	589±68
	1985	64±4	5	3.0±0.5	932±102
	1986	60±3	5	3.0±0.3	662±227
	1987	55±5	6	2.4±0.3	601±54
	1989	64±2	5	3.1±0.6	498±77
	1990	60±2	6	1.7±0.4	420±71

...continued

Table 3.5(continued) PCB residues in juvenile yellow perch. Values shown are means ± one standard deviation.

Location	Year	length(mm)	N[1]	% lipid	PCB(ng/g)
<u>Rice Lake</u>					
Wallace Point	1987	52±1	6	2.0±0.2	257±59
Spook Island	1977	71±2	10	3.6±0.2	1383±100
	1978	68±2	8	2.5±0.2	1365±121
	1979	65±1	7	2.6±0.3	1373±96
	1980	78±2	6	1.8±0.2	609±116
	1981	69±3	7	2.1±0.3	801±109
	1984	72±3	5	2.9±0.2	878±73
	1985	66±6	4	2.4±0.5	1945±253
	1986	68±3	7	2.9±0.4	1139±75
	1987	54±4	6	1.9±0.3	485±50
	1988	64±2	5	2.7±0.2	478±275
	1989	65±1	6	3.0±0.3	720±176
	1990	61±2	7	1.9±0.2	678±124
Idylwilde Point	1979	53±1	7	1.3±0.1	551±52
	1985	61±4	4	2.1±0.3	791±88
	1986	63±4	4	2.1±0.4	389±42
	1987	53±3	6	2.9±0.9	418±114
	1989	66±1	5	3.3±0.6	218±76
	1990	59±3	5	2.2±0.4	305±43
<u>Seymour Lake</u>	1987	55±1	5	1.8±0.5	202±38
<u>Trent River</u>					
Trenton:					
- above Domtar	1987	72±3	3	2.1±0.6	23±23
- below Domtar	1987	67±3	3	2.4±0.4	68±20
- Trent Bay	1987	64±2	3	2.0±0.4	70±26

[1] each sample analysed as a five-fish composite.